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Space-Based Ka-Band Direct Radiating Phased Array Antenna Architecture for Limited Field of View

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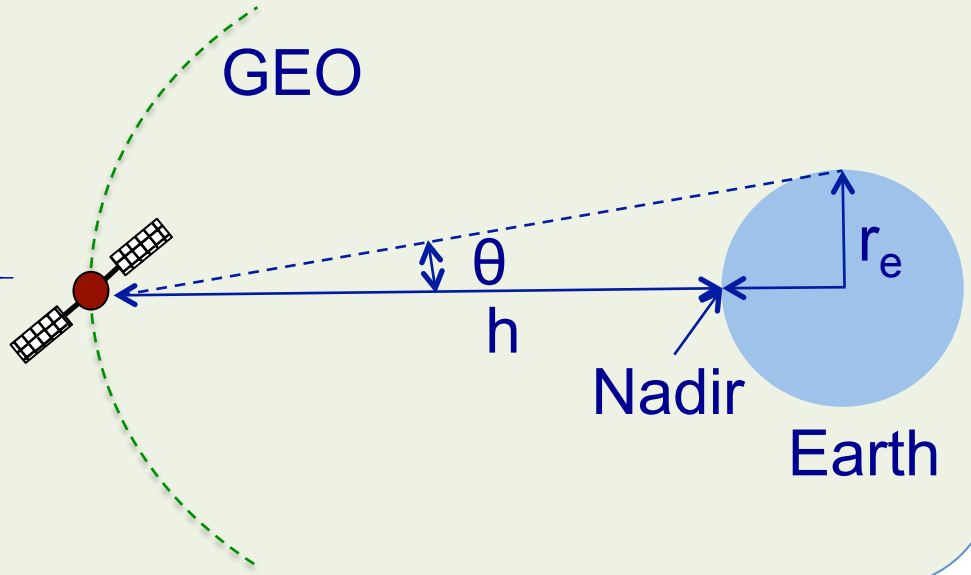
Problem Or Challenge

- To investigate the feasibility of designing a direct radiating phased array antenna as a replacement for the TDRS reflector antennas without compromising performance (EIRP = 63 dBW, G/T = 26.5 dB/K, bandwidth, etc.)
- Specifically, to investigate if a phased array with microstrip patch antenna elements coupled with Gallium Nitride (GaN) based amplifiers can meet the above requirements

Spaceborne Phased Array Antenna

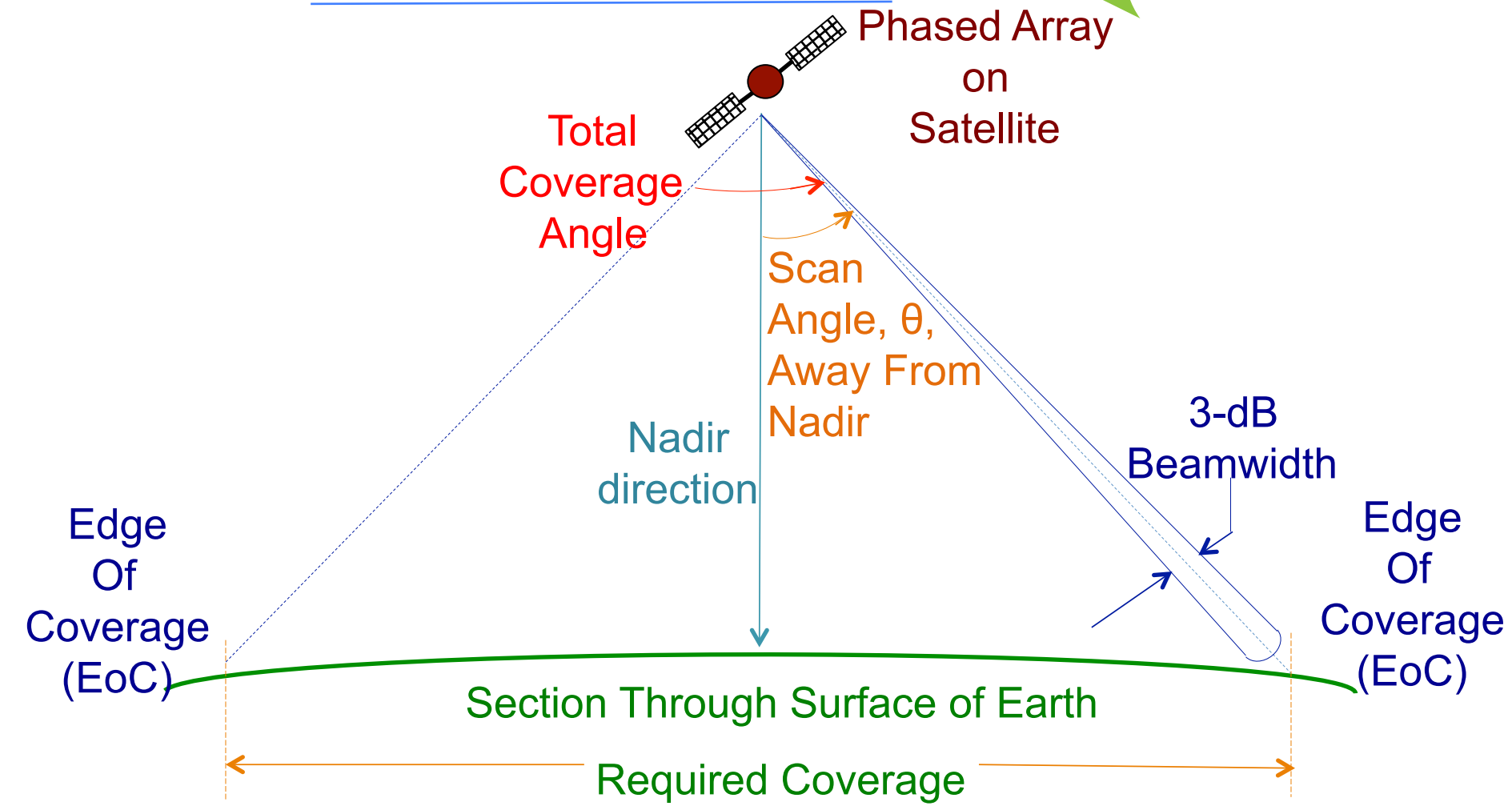
Direct Radiating Phased Array Antenna on Relay Satellite



The altitude h = 35,786 km above mean sea level & Earth's radius r_e = 6378 km

At such a distance, the Earth subtends a small conical angle of θ = ±8.7°. Consequently, the phased array onboard the relay satellite has to scan a limited field of view (LFOV)

Individual Beam Scan Angle Within a Coverage



Diameter of Spot Size on Ground is the 3 dB Beam Width

Array Design Methodology

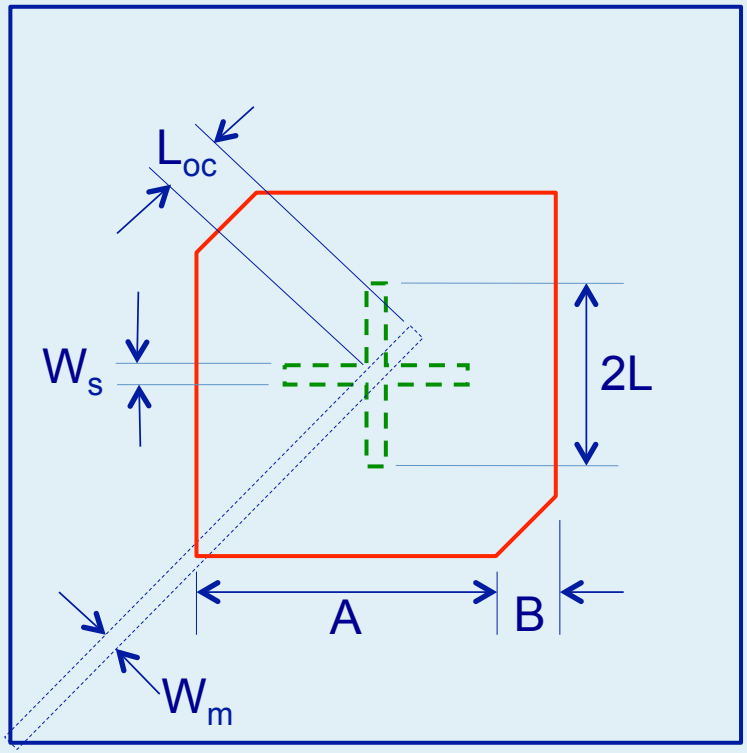
- Step 1: Antenna Element
- Step 2: Array Size
- Step 3: Element Size
  - The computations are carried out using the equations presented in the following reference:
    - A.K. Bhattacharyya, "Optimum Design Consideration for Multiple Spot Beam Array Antennas," 22nd AIAA Inter. Communications Satellite Systems Conf. & Exhibit, Paper Number AIAA 2004-3158, Monterey, CA, May 9-12, 2004.
- Step 4: Beam-Forming Network

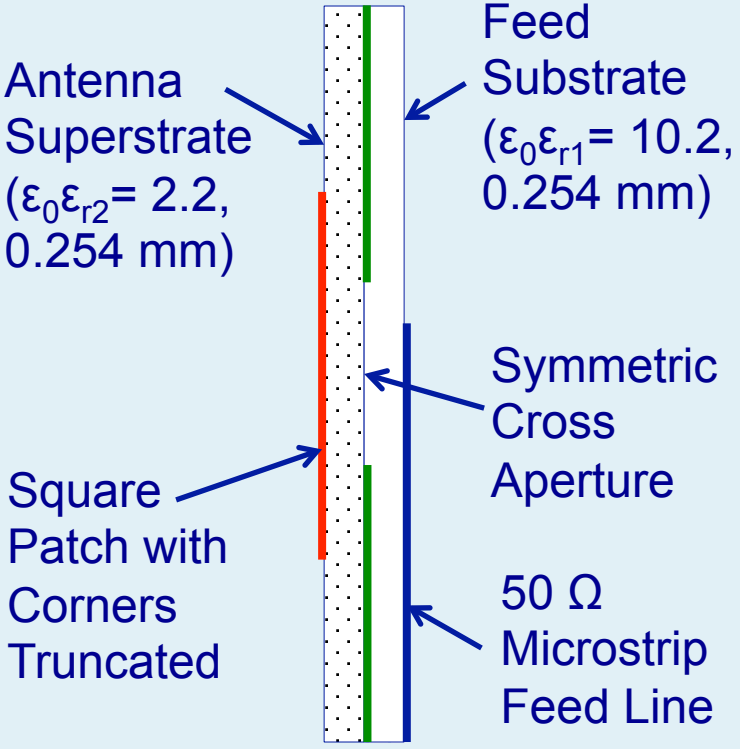
Antenna Element

★ Aperture Coupled Circularly Polarized (CP) Microstrip Patch Antenna

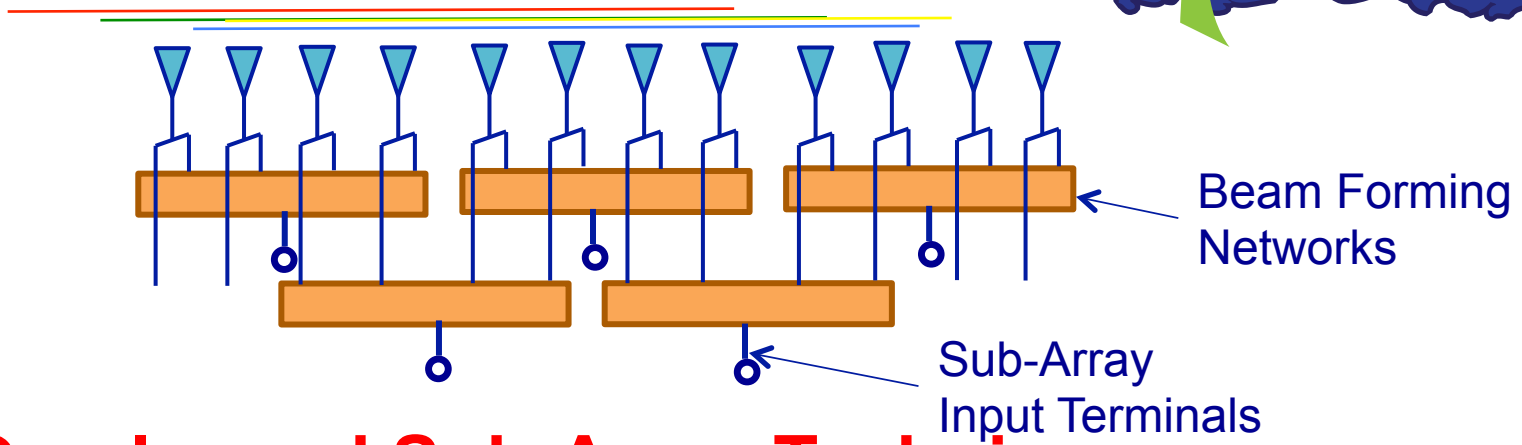
- **Key Advantages**
  - Patch antenna and the feed network reside on two separate dielectric substrates of different relative permittivity and thickness
  - Gain/bandwidth of the patch antenna and the efficiency of the feed network can be independently optimized
  - The two substrates can either be in intimate contact or can be separated by a small air gap to enhance coupling efficiency

Antenna Element & Feed Design





Beam-Forming Network



★ Overlapped Sub-Array Technique

- **Key Advantages**
  - ✧ Significant reduction in the number of control elements, such as variable gain amplifiers and phase-shifters, required to achieve the desired scan performance
  - ✧ Significant reduction in the array complexity, power consumption, overall size/mass, and cost.
  - ✧ Enhanced overall antenna reliability

Power Amplifier Modules

★ Gallium Nitride (GaN) Based Power Amplifiers (PAs)

- **Key Advantages**
  - GaN PAs have three to four times higher output power density than gallium arsenide (GaAs) based PAs
  - GaN transistors can operate at higher junction temperatures than GaAs transistors
- **Output Power**
  - Ka-Band GaN-on-SiC MMIC PAs with output power on the order of 5W are commercially available.

Conclusions

- ★ Design methodology for a direct radiating phased array Antenna for limited field of view (LFOV) has been presented
- ★ The number of array elements required for a given scan gain and scan angle has been presented
- ★ The edge of coverage directivity as a function of the element size has been presented
- ★ The optimum array elements size for the desired LFOV of ±8.7° has been presented
- ★ By integrating a GaN power amplifier with each sub-array input terminal the desired EIRP can be achieved
  - ➢ For example: It has been shown that an array of 1225 elements has a directivity > 40 dB and if each element radiates 1W, the target EIRP of 63 dBW can be achieved